Use of observations to assess the estimated cloud radiative feedback in warming climate in GCMs

Yoko Tsushima, Mark Ringer, Mark Webb,
Alejandro Bodas-Salcedo, Keith Williams

Met Office, Hadley Centre

CFMIP/EUCLIPSE meeting, 12 June 2013

Model’s cloud regimes have many biases

- Low clouds is less frequent and too bright. (Williams and Webb 2009, Nam et al. 2012)

Plus,

- Mid level cloud is less frequent
- Frontal regime is more frequent and less bright
- Anvil/Cirrus regimes are too few

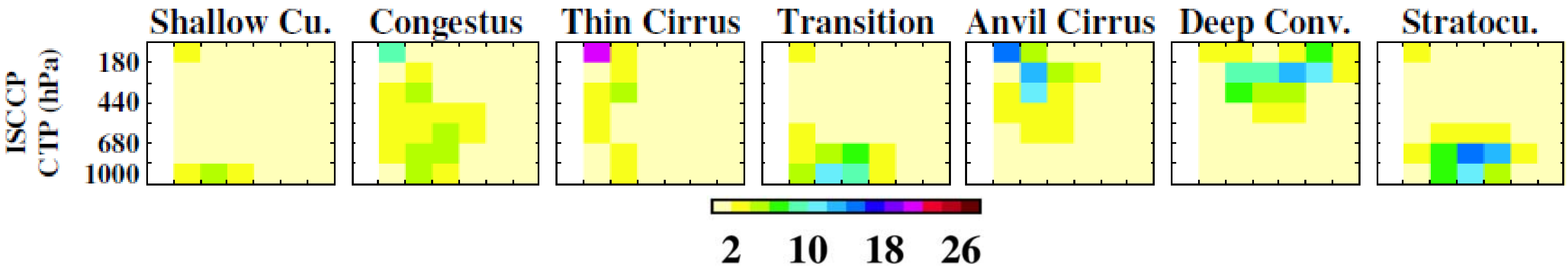
etc (Tsushima et al.,2012)

Attempt to constrain the uncertainty in cloud feedback in climate models by taking into account the bias in control climate simulation. Williams and Tselioudis, 2007(WT07), Williams and Webb, 2009 (WW09)

Question: Does the underestimate/overestimate of any property of a cloud regime in models relate to the magnitude of cloud feedback?

- In the seasonal variation, underestimate / overestimate of CRE of a regime in a model does not leads to an underestimate / overestimate of the magnitude of its seasonal variation, except anvil/cirrus regime. (Tsushima et al.,2012)
- How about in the global warming?

Cloud regime analysis based on Williams and Webb (2009) clustering method of amip and amipFuture run



Methodology

- Reference in-cloud mean albedo(α), cloud top pressure (CTP), total cloud cover (TCC) for each regime from Williams and Webb (2009).
- In GCM, (α, CTP, TCC) is calculated using the ISCCP-simulator. This is assigned to the closest , (α, CTP, TCC) of the observed regime, using a normalised minimum root-sum-square measure of distance.

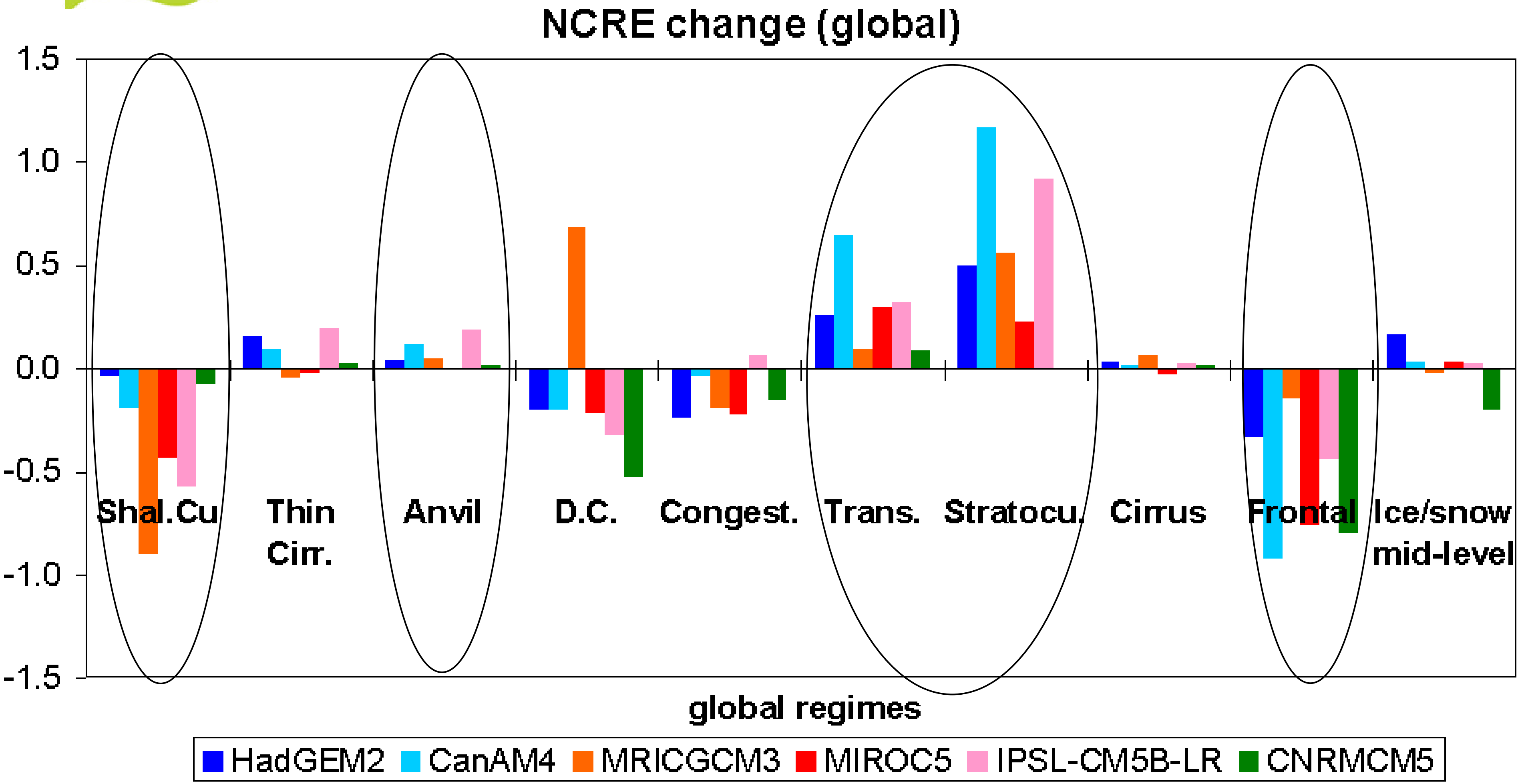
Model Experimental Data & Period

- Experiment: CMIP5 amip run & amipFuture run (hereafter ‘Future’) 10yrs (1979-1988) of each run.
- 6 models (HadGEM2-A, CanAM4, CNRM-CM5, IPSL-CM5B-LR, MIROC5, MRI-CGCM3)

Observation Data & Period

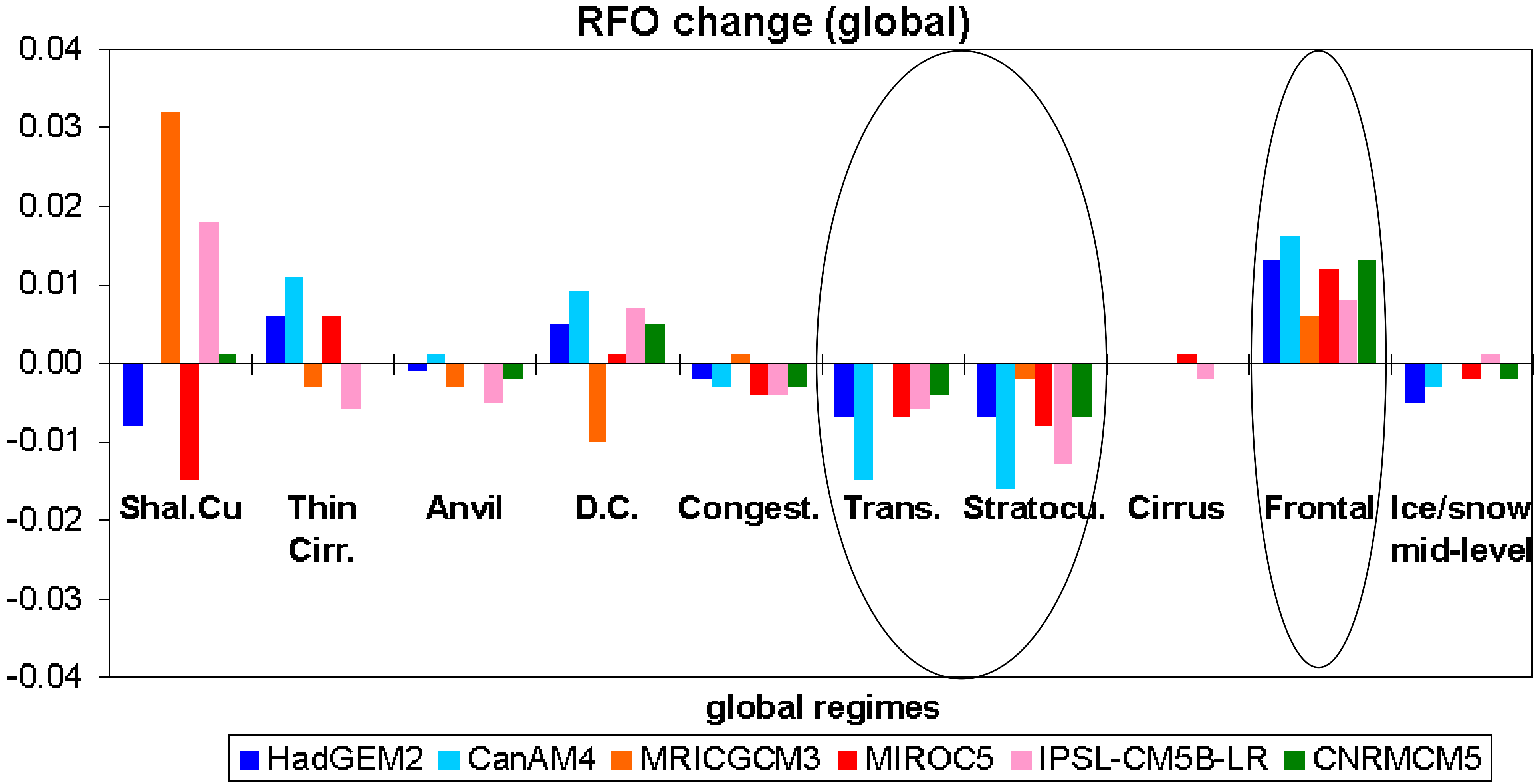
- Data: Daily ISCCP D1, ISCCP-FD (1985-1990)
- In-cloud mean albedo(α), cloud top pressure (CTP), total cloud cover (TCC) was calculated for each regime.

Change in Net Cloud Radiative Effect (NCRE) in Future



- Positive in Anvil, Transition and Stratocumulus regimes
- Negative in Shallow Cumulus and Frontal regimes

Change in Relative Frequency of Occurrence (RFO) in Future

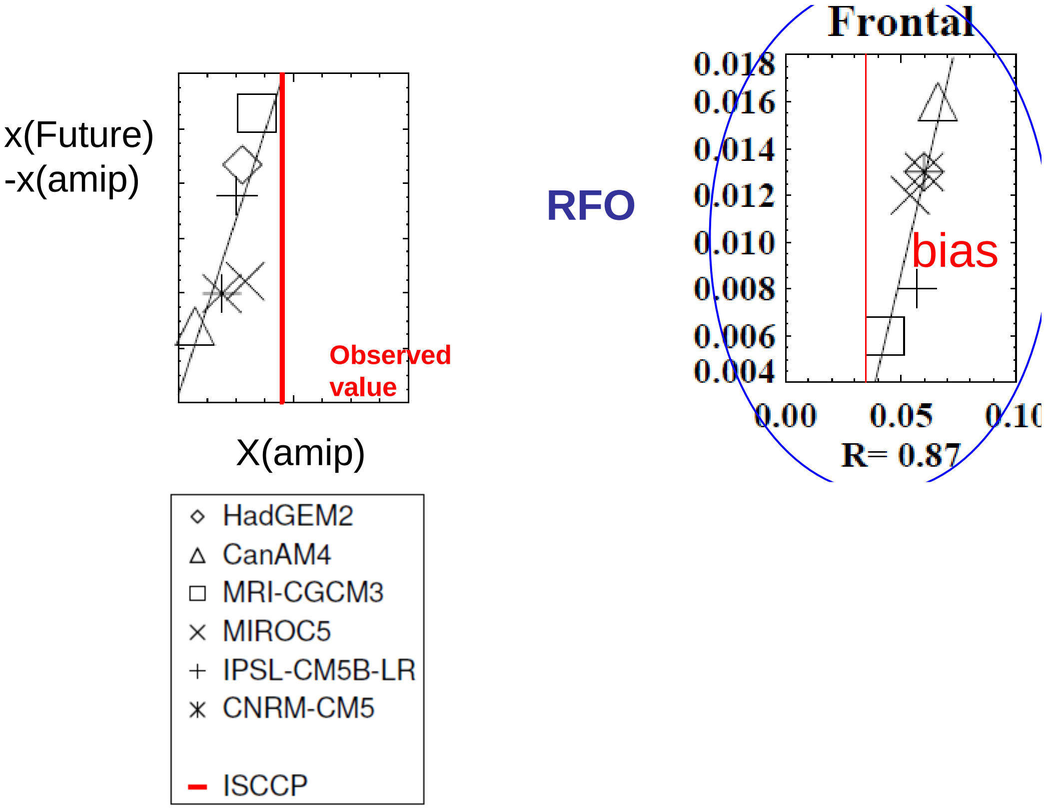


- Transition and Stratocumulus regimes decrease
- Frontal regime increase

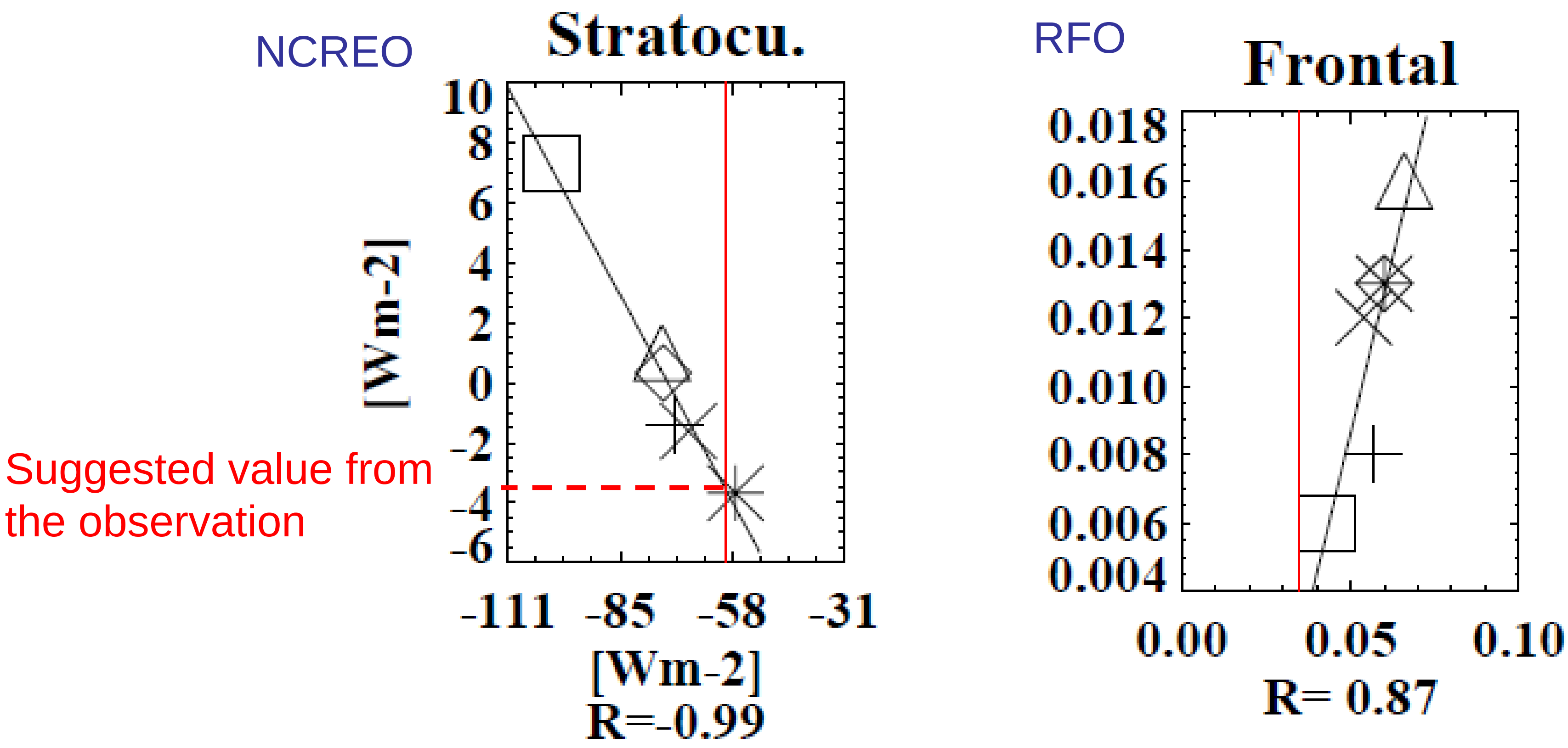
In these regimes, the RFO change dominates the change in CREs.

Question

- Do the magnitudes of the change in RFO and/or radiative property of these regimes in different models have any relationship to their control climate performance?

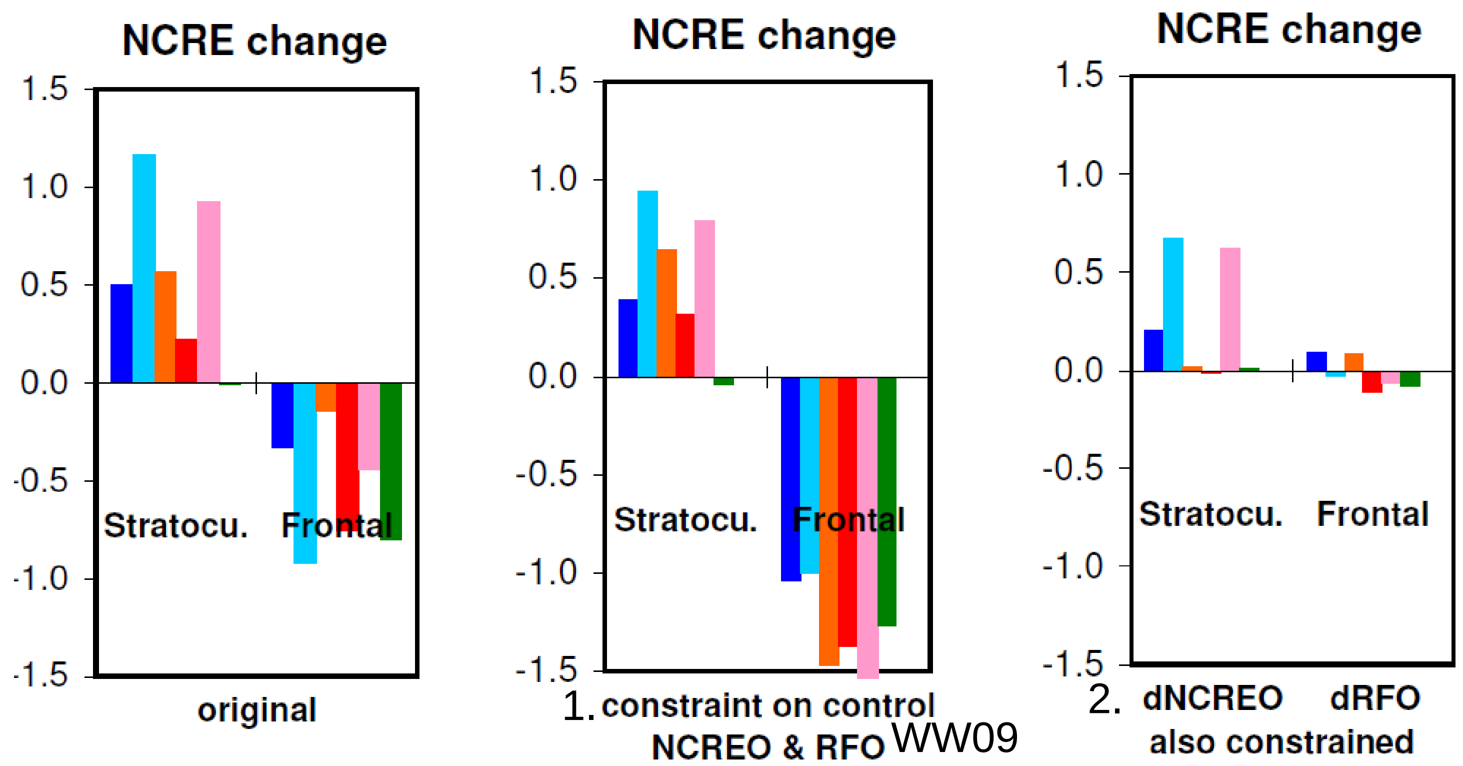

x(Future)
-x(amip)
Observed
value
X(amip)
HadGEM2
CanAM4
MRI-CGCM3
MIROC5
IPSL-CM5B-LR
CNRM-CM5
ISCCP
RFO
Frontal
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
bias
0.00
0.05
R= 0.87

If we believe this relationship comes from a modelled physics which also work in the real world,…



Models with more negative NCREO Stratocu regime show more positive response in Future.
Models with larger frequent Frontal regime have Frontal regime more frequently in Future.

NCRE change before and after constraints



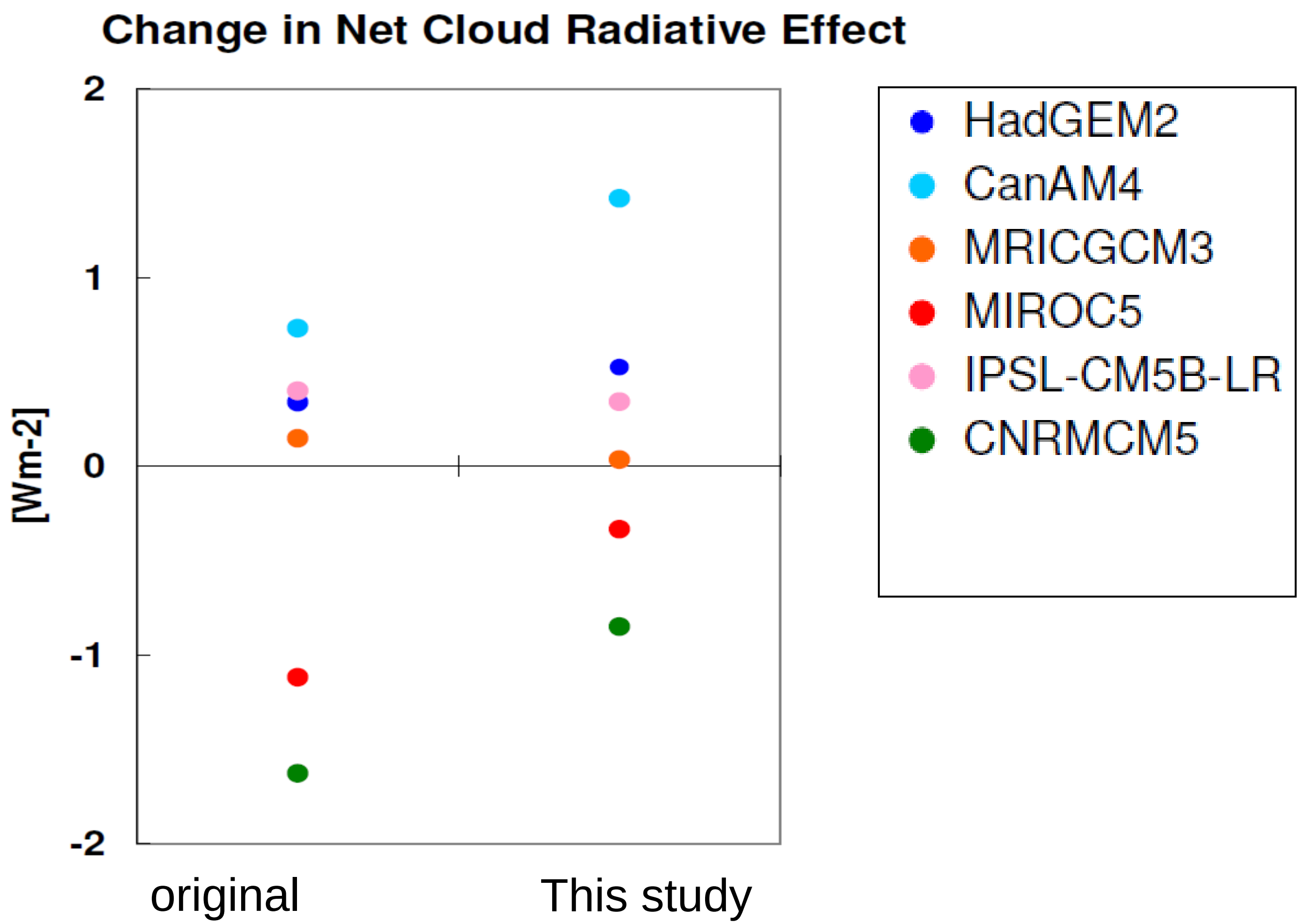
Constraint of the magnitude of the change in RFO and NCREO by the regression method works to reduce the inter-model spread of these regimes' NCRE change.

1. $$\Delta NCRE^{ctl\_obs}_{model} = NCREO_{obs}\Delta RFO_{model} + RFO_{obs}\Delta NCREO_{model} + \Delta RFO_{model}\Delta NCREO_{model}$$

2 for Stratocu. $$\Delta NCRE^{ctl\_obs.dncreo\_robs}_{model} = NCREO_{obs}\Delta RFO_{model} + RFO_{obs}\underline{\Delta NCREO_{robs}} + \Delta RFO_{model}\underline{\Delta NCREO_{robs}}$$

2 for Frontal $$\Delta NCRE^{ctl\_obs.drfo\_robs}_{model} = NCREO_{obs}\underline{\Delta RFO_{robs}} + RFO_{obs}\Delta NCREO_{model} + \underline{\Delta RFO_{robs}}\Delta NCREO_{model}$$

The global warming response which is dominated by RFO
plus
Compensation error between frequency of occurrence and cloud property



- Estimate from 4 models indicate more positive (less negative) cloud radiative response.
- The range of the NCRE by all regimes hardly decreases. (because stratocu response and frontal response is the opposite direction.)

Discussion

Met Office
Hadley Centre

- Breakdown into shortwave and longwave component in CRE shows correlations in more regimes.
- In this estimate, we take modest choice of the constraint (only for the net, statistically significant)
- In the real simulation, removal of a bias in a regime may affect the response of other regimes.
- The relationship between the amplitude of the seasonal variation and Future response was also investigated. Amplitude of in-cloud albedo forcing of Stratocu is the only one which shows significant correlation to the magnitude in climate response

Summary

- Common change in Future climate
  - NCRE positive in Stratocu and Transition regimes, negative in Frontal regimes.
  - RFO change dominates these changes.
- Present-day climate vs Future climate
  - Difference in the magnitude of a regime property in control climate in different models does not necessarily correlate to the difference in the global warming response magnitude.
  - Significant correlation is found in Frontal regime in RFO and Stratocu regime in in-cloud NCRE.
  - Application of the regressed value corresponding to the observation reduces the spread in model response of individual regimes.
  - Model-mean total response of CRE becomes 1Wm-2 more positive.
- The range of the overall estimate hardly decreases with these change, because of the opposite response between stratocu and frontal regime.
- This method could be useful to constrain the range of cloud radiative response in climate models.